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COSMIC-RAY TRAJECTORIES

SPACE PHYSICS LABORATORY, AFCRL

Cosmic rays--atomic nuclei, primarily hydrogen--approach the earth from all directions. When these particles encounter the earth's magnetic field, their trajectories are altered. Some in fact pursue an erratic course for several orbits around the earth. Just what trajectory the particle will follow depends on many things--particle momentum, charge, direction of approach to the magnetosphere, and the magnetic-field strength and configuration. The resultant trajectories are so complicated that predicting them is a mathematical problem of some magnitude.

Until recently only approximate solutions to this problem were available since each trajectory calculation involves several thousand iterative steps to reach a solution. With computers, this problem has been made tractable.

For the past two years, M. A. Shea and D. F. Smart of AFCRL, and K. G. McCracken of the Graduate Research Center of the Southwest in Dallas, Texas, using computers, have plotted trajectories of cosmic rays in the geomagnetic field. Their calculated values are more consistent with the results of observational cosmic-ray data than previous values. Already, scientists from a number of countries, including Australia, England, Canada, Argentina, and South Africa, have successfully applied these new values in analyzing cosmic-ray data.

The results of this intensive research investigation are contained in a recently issued AFCRL report, "A Study of Vertically Incident Cosmic-Ray Trajectories Using Sixth Degree Simulations of the Geomagnetic Field," (AFCRL-65-705). This 350-page report consists largely of computer-generated tables of the trajectories of particles with a different momentum and charge at more than 130 locations around the world. These results are the most accurate and complete determinations of cosmic-ray trajectories made to date.

In considering the trajectory of a given particle, it is convenient to consider momentum and charge as a single quantity. This quantity is called the particle's "rigidity," and is the ratio of momentum per unit charge. All particles having the same rigidity, whether an individual proton or a heavy nucleus, will follow the same path through a magnetic field if they enter the field at the same place and from the same direction. The AFCRL report deals with vertical "cutoff rigidities." Such a cutoff rigidity is defined as the lowest rigidity a particle may possess and still arrive at a specific point on the earth's surface from the vertical direction. The three investigators have made a signifi-

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cant refinement to this definition which makes it possible to calculate the effects of the geomagnetic field more accurately. This new definition is called an "effective cutoff rigidity." At the magnetic equator, where the particle must perpendicularly traverse the geomagnetic field, the "effective vertical cutoff rigidity" is more than 15 billion volts, while at the magnetic poles, where the particles are essentially parallel to the field lines, it is theoretically zero.

From this one would expect to observe (by detecting a cascade of secondaries at the earth's surface) a minimum cosmic-ray intensity at the magnetic equator, and a maximum intensity at the geomagnetic poles. This minimum is in fact observed at the magnetic equator; but the maximum intensity is not correspondingly observed at the geomagnetic poles. Contrary to expectations, there is no localized area of maximum intensity. The maximum is rather uniformally distributed throughout the entire regions above 55 degrees geomagnetic latitude.

However, if the earth had no atmosphere, or if our observations were made well above the atmosphere, cosmic-ray maxima would be found near the geomagnetic poles, as expected. Why then do we not observe these conditions on the ground? It has to do with the particle's cutoff rigidity--which can be thought of as a kind of threshold energy. All particles above 1 bv are able to penetrate the earth's magnetic field in all regions above 55 degrees geomagnetic latitude. All particles with rigidities lower than 1 bv are absorbed by the earth's atmosphere (without creating the cascade of secondaries), and are not detected on the earth's surface. This applies whether they enter at 55 degrees or at 90 degrees geomagnetic latitude, or at any point between.

Because cosmic-ray trajectories are directly influenced by the configuration of the magnetic field, which varies diurnally, seasonally, and with solar-cycle variations, it is possible to derive information on the changing magnetic field by observing cosmic-ray events. Also, because the calculations of cosmic-ray rigidities are equally valid for solar protons, the calculation techniques

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JACOB SEIDEN
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developed under this study can be used to evaluate the trajectories of these solar particles as well.

The three investigators have thus far used about 1500 hours of computer time on a Philco 2000 computer to make their calculations. This work is now being extended to produce a world-wide grid of cutoff rigidities. A 15-by-15-degree grid has already been completed, and is currently being refined to include latitude intervals of 5 degrees. With this vertical cutoff rigidity map, the trajectories and rigidities for cosmic rays detected at any point on the earth may be determined. ★

SPONTANEOUS EMISSION-HOW SPONTANEOUS IS IT? (Electromagnetic Radiation)

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

Most of us at one time or another have examined the old question as to whether or not, if a tree fell in the forest and no one was around to hear it fall, there would be sound--a question that, on analysis, really doesn't have much meaning.

A superficially related question exists in electromagnetic theory--but with the difference that the question has real meaning and is of major theoretical importance. The question is this: if there is no absorber of electromagnetic radiation, can electromagnetic radiation be emitted? In 1922 it was first postulated (by Tetrode) that there can be no emission from a particle if there is not a second particle to absorb the emission. In his paper, Tetrode stated, "The sun would not radiate if it were alone in space and no other bodies could absorb its radiation. . . One might accordingly adopt the opinion that the amount of material in the universe determines the rate of emission." Wheeler and Feynman extended this concept in the late 1940's, showing that the absorbing particle, instead of sitting passively and waiting to absorb the emission, is actually a part of the emission process. This is an intriguing concept--but there is nowhere on the horizon any approach to an experiment to prove or disprove it.

The whole matter falls under the general heading of quantum electrodynamics (where the equations of classical electrodynamics are recast into quantum mechanics). Leading theoretical physicists have devoted inordinate effort to refining these equations during the past several decades. In fact, Schwinger, Feynman and Tomonaga received the 1965 Nobel Prize in physics for work in this field. But, in spite of the wondrous formulations that have evolved, the fact remains that radiation theory is still not a complete and consistent part of physics.

In a recent AFCRL report, "A Discussion of the Wheeler-Feynman Absorber Theory of Radiation," Dr. Ronald G. Newburgh examines one theory of radiation and provides some extensions. In another paper, soon to be issued as an AFCRL report, "A Survey of Classical Radiation Theory," Dr. E. J. Post surveys the accumulated product of our knowledge in quantum electrodynamics. Both papers provide interesting new perspectives, but only the Wheeler-Feynman theory will be touched on here.

Reduced to its simplest terms, quantum electrodynamics is concerned with the interaction of an electron and an electromagnetic field. And the primary theoretical problem is that of explaining how an accelerating electron can emit an infinity of photons. So the object of the theorist is to envision a system in which energy and momentum are conserved; one approach is to invoke radiative reaction. The problem takes him into that grey area in which physical entities merge into purely mathematical and even metaphysical constructs.

The Wheeler-Feynman theory fuses a number of concepts: 1) the field is not an independent entity with degrees of freedom of its own; the motion of a given particle is determined by the sum of the fields produced by all other particles; 2) a particle cannot act on itself--that is, an electron cannot spontaneously emit a photon; 3) the sym-

metry between past and future prescribes the fields. Here we find ourselves confronted with the conceptionally difficult notion of retarded and advanced potentials. The very definition of "potentials" varies from discipline to discipline with only loose unifying threads. In one sense, potentials can be considered only as mathematical additives--involving differentials, vectors and tensors--needed to show conservation of energy momentum.

To satisfy energy-momentum relations, one must have, in addition to the emitting electron and its emitted photon, a third body--which, as we have said, is the absorber. Together these comprise a system, but a system that, through the mechanism of retarded and advanced potentials, operates forward and backward in time. Of course, in the real world, we don't have just one absorber. Newburgh, in his commentary on the Wheeler-Feynman theory, considers the more realistic system in which, for every emitter, there may be something on the order of 10^{23} absorbers. In the natural system, one may consider the effects of the absorbers as consisting of many small impulses transferred to the emitter. Because of the large numbers of absorbers (10^{23}), one may visualize many tiny effects continuously arriving at the emitter. This is analogous to the Brownian motion of molecules in fluids. At the moment of emission, these effects "sum," thus "causing" the electron to emit its stream of photons and providing fuel for their continuous emissions.

On first meeting the concept of advanced effects and the necessity of an absorber for emission, one feels that common sense has been violated. After we grow accustomed to this precept, it offers the satisfaction of logical economy and does not appear physically unreasonable. ★

TIME-LAPSE VIDEO RECORDING EQUIPMENT INSTALLED AT SACRAMENTO PEAK

SPACE PHYSICS LABORATORY, AFCRL

With the delivery of a special video tape recorder built by RCA, stop-motion video tape pictures of sunspots will soon be made at AFCRL's Sacramento Peak Observatory. The video tape produces time-lapse photography of the type sometimes used to speed up slowly evolving processes such as the growth of plants.

The new equipment will permit Sacramento Peak astronomers to analyze with greater speed and precision the growth and movement of sunspots. It is difficult for the astronomer to be aware of the many changes in sunspot development that take place when these are viewed on a real-time basis. The new equipment will help advance AFCRL's over-all program for predicting safe periods during which there is an absence of solar proton showers. These high-energy, ionizing particles erupt periodically from the sun and are closely associated with sunspot activity.

Time-lapse photography of sunspots has been made previously at the observatory on motion-picture film. Delays involved in film processing, however, have resulted in corresponding delays in making predictions. Since a magnetic-tape record of TV pictures needs no processing, the observatory staff can replay a sequence of stop-motion pictures immediately, and make judgements.

When the TV recorder is in operation, it will record two television frames every 30 seconds. A replay of only 15 seconds of such a recording represents 112.5 minutes of actual observation, or a speed-up of the scene of 450 times.

The machine being modified for the assignment is RCA's type TR-4, a fully transistorized unit widely used by the TV networks and stations for recording and playing back programs and commercials. It will record pictures made by a vidicon camera connected to observation instruments on a 12-foot telescope.

electrofluid dynamic working media for direct energy-conversion processes

MICHAEL HAWES, Thermomechanics Research Laboratory, ARL

One highly interesting electrofluid dynamic (EFD) process is the direct conversion of fluid dynamic energy into electricity. The basic process involved can be summarized briefly (see Fig. 1): charged particles of one polarity are transported in a fluid working medium through a conversion section against an electrostatic field produced by the deposition of charge on the collector electrode. It is similar to the process in the Van de Graaff electrostatic generator except that a flowing gas replaces the mechanically driven belt. Using a gas has several advantages; the transport speed of the charges can be far higher, and the charges are distributed throughout a volume space rather than being limited to a surface area.

It is important for the performance of an EFD generator that the gas have certain properties. In a generator which employs charged colloids as the transported particles, desirable properties of the gas are a high dielectric strength and a low molecular weight. Unfortunately, the low-density gases, hydrogen and helium, do not have a very good dielectric strength. If, however, it should be possible to find some additive which increases the dielectric strength of one of these gases to a value nearly equal to that of air, while increasing the molecular weight only slightly, a very desirable medium would be achieved. The following table illustrates the improvements that could be gained in power density and efficiency at an operating pressure of 20 atmospheres:

GAS	POWER DENSITY	STAGE EFFICIENCY
Air	400 watts/cm^2	41%
Hydrogen	290 watts/cm^2	45%
Hydrogen and Additives	800 watts/cm^2	70%

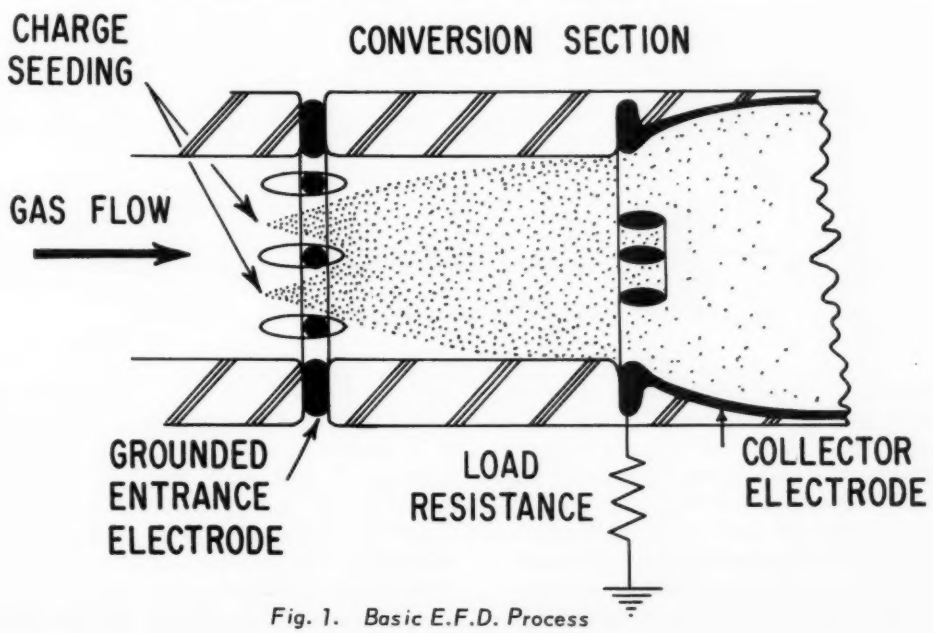

Fig. 1. Basic E.F.D. Process

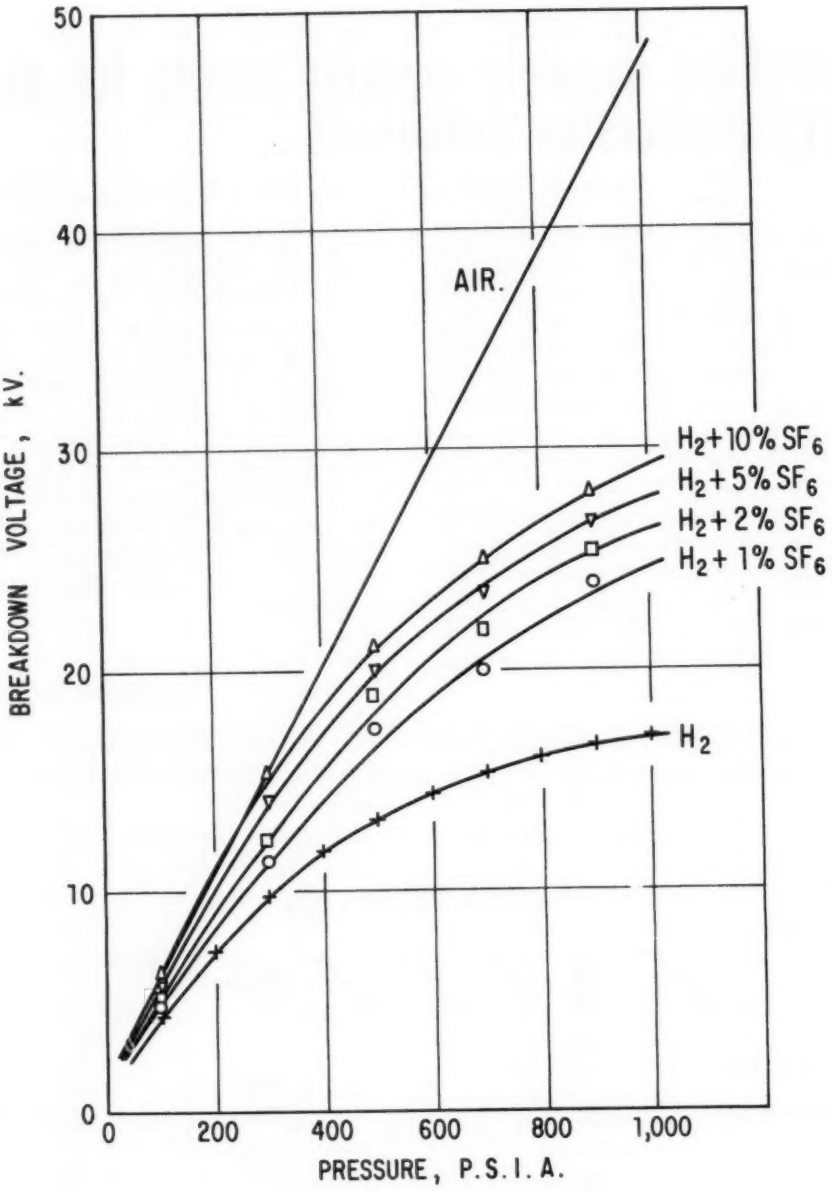

Fig. 2. Breakdown Voltages of Hydrogen–SF_6 Mixtures

An investigation was carried out at ARL to try to synthesize a good working medium of low molecular weight by increasing the dielectric strength of hydrogen or helium. Sulfur hexafluoride and dichlorodifluoromethane (Freon-12) are attractive substances to employ as the breakdown inhibitor additives because of their high breakdown voltage values as well as other favorable properties. It is known that there is a disproportional increase in dielectric strength of a gas at low additive concentrations; this implies large increases in strength at small density increases, a welcome trend.

Dielectric strength values are not amenable to calculations; they must be determined

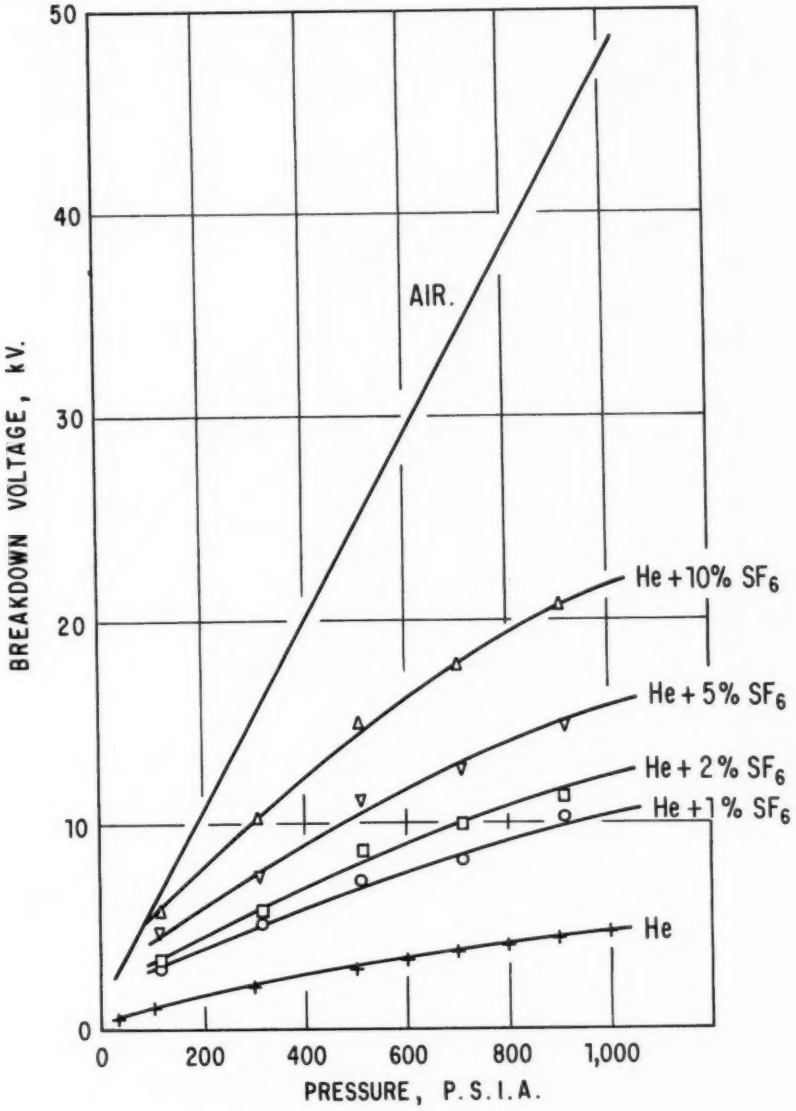

Fig. 3. Breakdown Voltages of Helium–SF_6 Mixtures

experimentally for each substance of interest. Dielectric strengths were determined for the parent gases, hydrogen and helium, with additive percentages of 0, 1, 2, 5 and 10 in each case. Furthermore, as pressures up to 600 p.s.i. have been used in the conversion section of the ARL experimental EFD generator, it is necessary to determine the dielectric strength of each mixture at pressures at least up to this level. Actually, the investigation was extended to cover the pressure range 0-1,000 p.s.i.

The experimental apparatus consisted of two 1 3/8-inch diameter spherical electrodes mounted within a 6-inch diameter stainless-steel test chamber. Spacing was maintained constant at .010-inch in all tests so that an essentially uniform field resulted. The

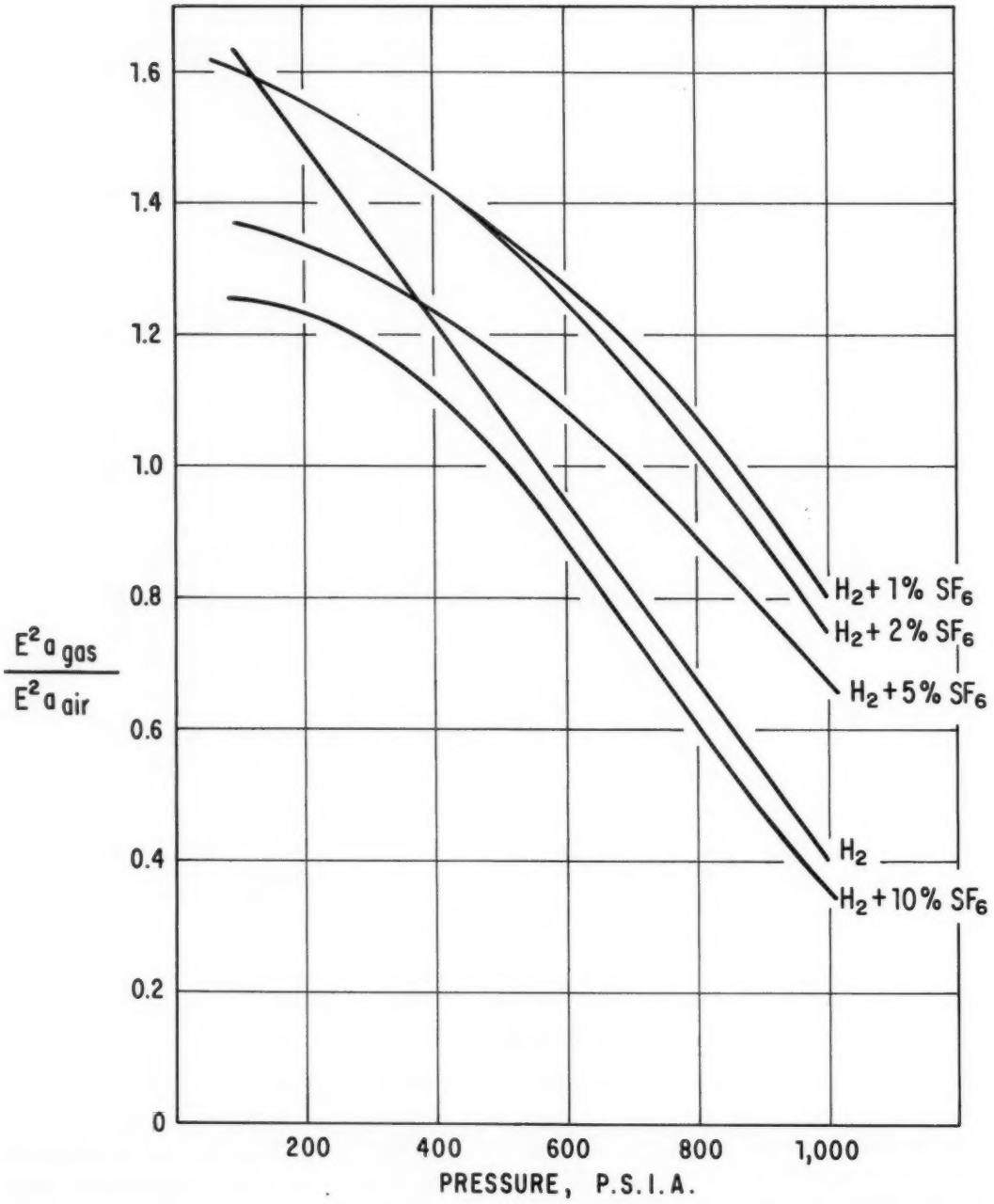

Fig. 4. Relative Merits of Hydrogen–SF_6 Mixtures (Power Considerations)

dielectric strength is then readily available from a knowledge of the breakdown voltage. D-C voltage from a 0-60 kV continuously variable commercial power supply was employed throughout the investigation.

Graphical results are shown in Figures 2 and 3 for the case where SF_6 was the breakdown inhibitor added. This additive proved to

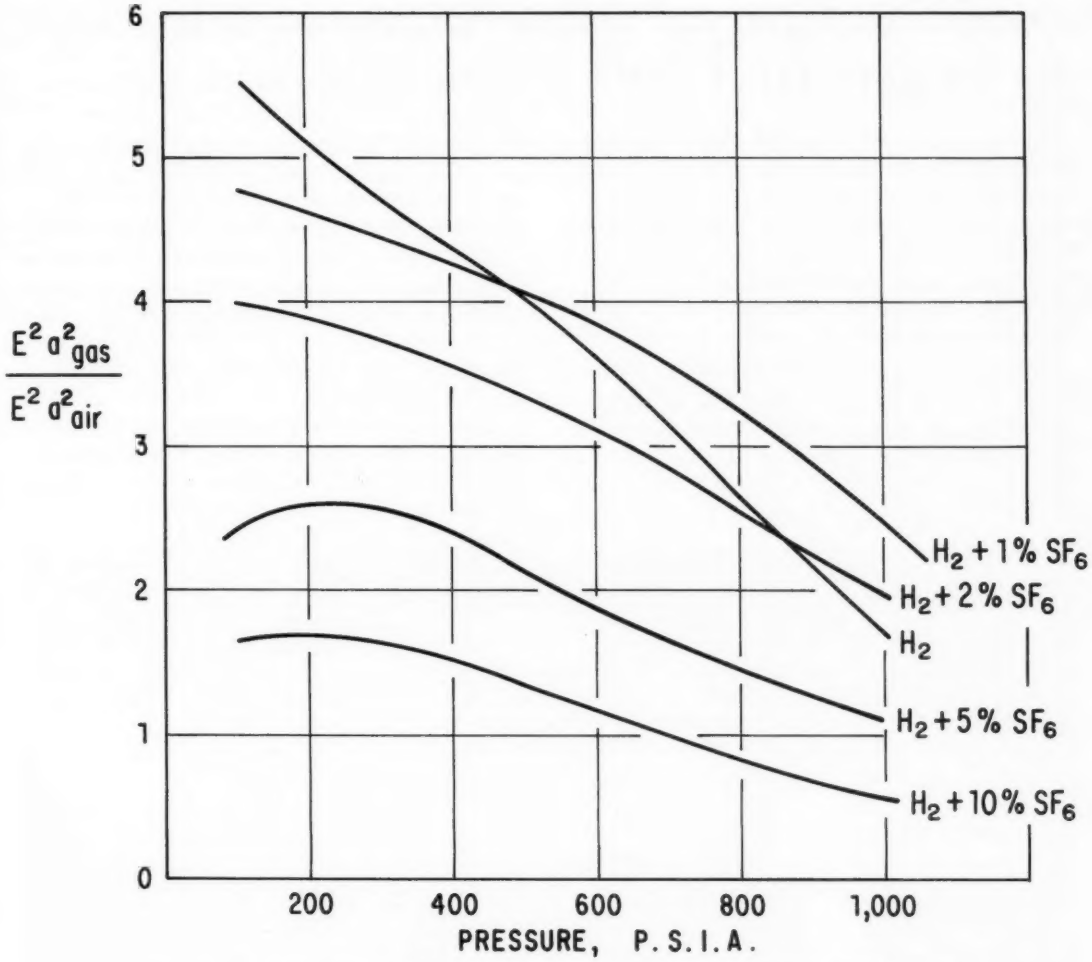

Fig. 5. Relative Merits of Hydrogen–SF_6 Mixtures (Efficiency Considerations)

be somewhat more effective than Freon-12 at all pressures. The curve for air as determined experimentally during the investigation is also shown on these graphs for comparison purposes.

It is seen that a hydrogen-10% SF_6 mixture has a dielectric strength approximately equal to that of air in the low-pressure regime up to 300 p.s.i., but that this mixture has a molecular weight of 16.4, which represents an appreciable increase over the value of 2 for hydrogen. However, the magnitude of the product E^2a, where E is the gas dielectric strength and a the speed of sound in the gas, is the criterion for selecting the best gas or mixture for power-production purposes in an EFD generator. Similarly, the gas with the highest value of the product E^2a^2 yields the best stage efficiency for the process.

These parameters are plotted in Figures 4 and 5 over the pressure range investigated, and are nondimensionalized by dividing by the corresponding value for air at the same pressure. It can be seen that a gas composed of hydrogen-1% SF_6 is an attractive mixture to employ as an EFD working medium over a wide pressure range. ★

construction of solar vacuum telescope to begin in 1966

SPACE PHYSICS LABORATORY, AFCRL

Construction of a unique solar telescope at the Air Force Cambridge Research Laboratories' Sacramento Peak Solar Observatory, Sunspot, New Mexico, will begin in the spring of 1966. Design concepts for the telescope were established by an AFCRL scientist, Dr. Richard Dunn. Plans call for its completion early in 1968.

The $3.16-million telescope will be 326 feet long; 200 feet of this length will be beneath ground level. The above-ground segment will rise 126 feet on a peak of the Sacramento Mountains, which are 9,200 feet above sea level. With the completion of the new telescope, the Sacramento Peak Observatory, already a major solar research center, will become one of the most complete facilities in the world for the study of solar phenomena.

The above-ground portion of the telescope will consist of a truncated, cone-shaped tower and associated laboratory buildings. The base of the 126-foot tower will have an inside diameter of 40 feet. The diameter will narrow to 20 feet at the top.

Atop the tower will be a rotating turret for tracking the sun in elevation and azimuth. Light from the sun will pass through a quartz window having a 30-inch aperture onto flat

This is a model of the solar vacuum telescope. This model was photographed at its proposed location atop Sacramento Peak.

mirrors mounted in the turret. The mirrors will direct the light down a long 320-foot tube to a spherical mirror at the bottom. This spherical mirror will have a diameter of 64 inches and focal length of 180 feet. By tilting the mirror, light can be directed upward to any one of 5 observation ports in the associated ground facilities.

Two design features should give the telescope exceptional flexibility and resolution. The first is in the mounting of the optical system. The entire optical system, including the 320-foot interior tube and associated instrumentation, will rotate as the sun is tracked. This system will weigh approximately 250 tons. The second feature is that the optical system and associated instruments will be placed in a vacuum. The purpose of the vacuum is to eliminate air turbulence, which can greatly affect the resolution of the telescope. An added advantage of the vacuum is the elimination of dust from optical surfaces that would degrade resolution and sensitivity. Two vacuum pumps will evacuate the entire optical system and associated instruments to working pressure in about six hours, displacing 17,000 cubic feet and obtaining a vacuum of .25 torr, which corresponds to an altitude of 180,000 feet.

The new facility is closely linked to the nation's space programs. Of prime concern are high proton showers associated with sunspot activities. These showers provide a great potential hazard to man in space, and degrade electronic equipment. The study of characteristic features on the surface of the sun which give rise to these showers will receive special emphasis. From these studies, AFCRL scientists hope to extend the period over which they can predict the onset of proton showers. Predictions can now be made with considerable accuracy over a 10-day period.

In addition to research leading to the more precise prediction of dangerous proton showers, the new telescope will be used for research on a range of solar phenomena. Solar activities have a profound effect on the earth's weather and on communication and detection systems. AFCRL scientists hope to obtain a clearer picture of solar-terrestrial relationships. ★

BAND STRUCTURE OF ZnO

Y. S. PARK, Solid State Physics Research Laboratory, ARL

A detailed study of the absorption and reflection spectra of ZnO crystals has recently been made in the region of intrinsic absorption in this Laboratory. (1) From these results, we have proposed an alternate band assignment different from that previously reported by Thomas. (2)

According to group symmetry studies by Birman, (3) the fundamental exciton absorption bands of the wurtzite structure in II-VI compounds at k=0 consist of the s-like conduction band and the p-like valence band. The valence band is split into three doubly degenerate states due to the spin-orbit and crystal field effects. The conduction band has a Γ_7 symmetry. The top valence band (A-band) has Γ_9 symmetry while the two lower valence bands (B and C-bands) have Γ_7 symmetry. The selection rules allow a $\Gamma_9 \rightarrow \Gamma_7$ transition for light polarized in the orientation $E \perp C$; $\Gamma_7 \rightarrow \Gamma_7$ transitions are allowed for both modes of polarization ($E \perp C$ and $E \parallel C$). On the basis of this model, the optical spectra of CdS(4), CdSe(5) and ZnS(6) crystals were successfully explained.

The fundamental exciton spectra of ZnO crystals were first investigated by Thomas. (2) On the basis of polarization experiments, he proposed that in ZnO, unlike in other II-VI compounds, the symmetries of two top valence bands were reversed. We have found that the line interpreted by Thomas as the ground-state A exciton transition is actually of impurity origin, and that the band symmetries and valence band ordering in ZnO are the same as in other II-VI compounds.

Figure 1 shows the absorption spectrum of ZnO taken at 1.2°K in polarized light. The essential feature of this spectrum is the existence of three intrinsic exciton bands (the A-, B- and C-bands) with the associated excited states (n=2,3,4) observed for the A-Band. The line at 3653.42Å (A, n=1) and the A, n=2,3,4 states of exciton A are seen

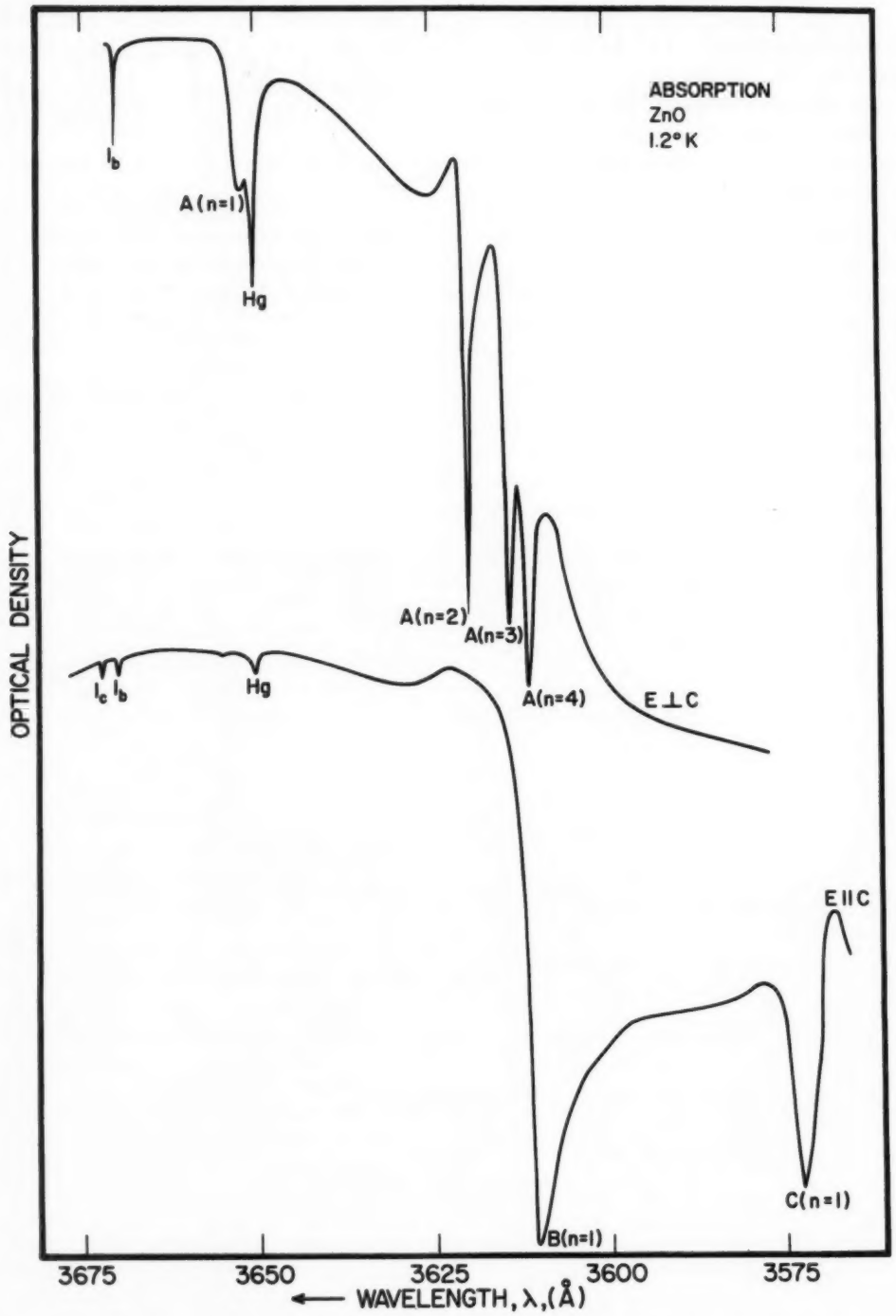

Fig. 1. Absorption Spectra of a Vapor-Grown ZnO Platelet at 1.2° K in Polarized Light.

only in E⊥C. The A, n=4 state and the B, n=1 state are very close together and are not resolved. The lines at 3610.81Å (B, n=1) and 3572.86Å (C, n=1) appear strong for light polarized with E ∥ C. The absorption of the C exciton for E⊥C is weak.

The impurity line at 3669.66Å (I_b), considered as the ground-state A exciton transition by Thomas, is preferentially polarized for E⊥C. We interpret this line as a bound exciton line resulting from an ionized donor complex. Some of the experimental evidence that points to the extrinsic nature of the line follows:

a) The intensity of line I_b is always less than that of the 3653.42Å (A, n=1) line. The ground-state A exciton would be expected to be the most intense transition.

b) Line I_b splits in a magnetic field as would be expected for a charged donor complex arising from a $\Gamma_7 \rightarrow \Gamma_9$ transition. (7)

c) The variation of the strength of I_b in different crystals of ZnO. In the hydrothermally grown crystal, it is completely absent.

d) The very different temperature dependence of line I_b from that of the ground-state exciton. At 180°K, I_b line disappeared while the A-exciton line persisted. If these two lines were due to the A and B intrinsic exciton transitions in ZnO, it would be reasonable to assume that they would both show very similar temperature dependence.

e) The fact that line I_b disappears when the crystal is baked in Zn vapor demonstrates the extrinsic nature of the line.

From the intrinsic exciton energies, a number of relevant parameters relating directly to the band structure can be determined. Using the ground-state exciton energy (A, n=1) and the first excited-state energy (A, n=2), and assuming the exciton has a hydrogen-like set of energy levels, the exciton binding energy is calculated to be E_B=0.042 eV. At 1.2°K, the energy gap is 3.435 eV.

From these results, we conclude that the band symmetries and valence band ordering in ZnO are the same as in other II-VI compounds. The band structure of ZnO at k=0, together with the band symmetry, is shown in Fig. 2.

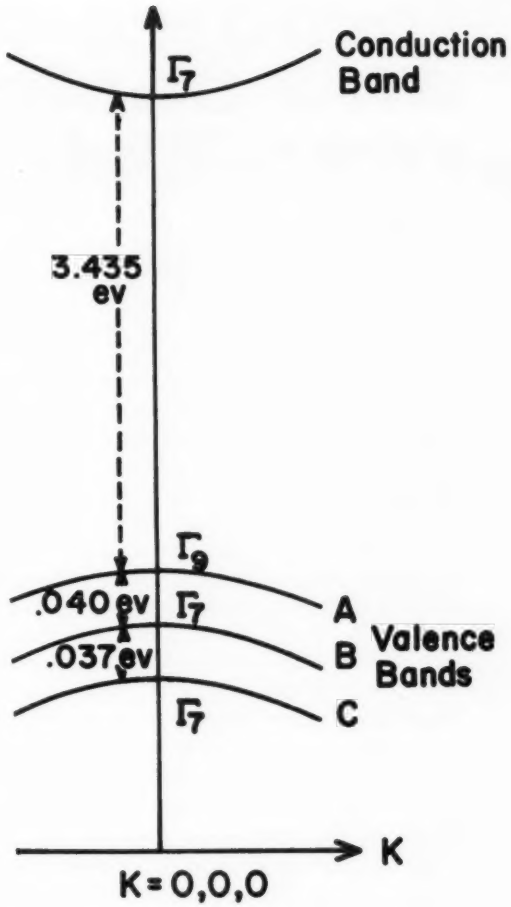

Fig. 2. The Experimental Values of the Band Structure of ZnO at k=0.

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tomorrow's weapons and basic research

DR. WILLIAM L. RUIGH
Directorate of Chemical Sciences, AFOSR

Tomorrow's Weapons is the title of a recent book by Brig. Gen. J. H. Rothschild, USA (Retired), former Commanding General, U.S. Army Chemical Corps., which is responsible for research in chemical, biological and radiological warfare (CBR). This book discusses the tabooed subject of CBR weapons and points out that, in recent years, practically none of our responsible military or civilian governmental officials have openly discussed the subject of CBR warfare. In the introduction to his book, General Rothschild says that Russian officials discuss the subject freely, and openly state that these weapons will probably be used on a large scale in future wars. These being the facts of life, not to be prepared to defend our troops and civilian population against CBR weapons would be folly indeed.

One of the most important areas of research in gas warfare is the measurement of gas dispersal and the rate at which the concentration changes with many factors. Thus, some of the toxic materials are sensitive to water and are decomposed by it, whereas others are sensitive to light. To measure the minute concentration of these materials in the field is an extremely difficult problem. What complicates the picture is that the analysis often has to be done in the presence of relatively nontoxic degradation products which contain the same elements as the original material. Where does basic research enter into the picture? The question is sometimes difficult to answer; but it seems obvious that highly technical weapons, like chemical gas weapons, need a very highly developed state of technology to solve problems associated with their use. For this reason the Directorate of Chemical Sciences, AFOSR, has supported research efforts in those categories which sustain and strengthen our capabilities in certain forseeably important areas. More specifically, the Directorate of Chemical Sciences has usually supported a modest program of three or four investigations in the chemistry of phosphorus compounds. Part of the reason for its support is the long-range interest of the Air Force in phosphorus compounds, since some of them are potent toxic war gases.

The research effort of Dr. K. Darrell Berlin at Oklahoma State University, entitled "Nucleophilic Displacements on Trivalent Phosphorus," is far from the field of toxic phosphorus war gases, but is good interesting phosphorus chemistry. While working in this area, a need arose for versatile analytical methods; the principal one used was gas chromatography. Dr. Berlin published a paper recently called "Gas Chromatographic Analyses of Organophosphorus Compounds Using a Hydrogen Flame Ionization Detector. The Use of Chromosorb Gas as a Solid Support." This paper was published in the Journal of Gas Chromatography for August 1965. The abstract of this paper follows:

> "The analyses of several classes of organophosphorus compounds are described. Some of the problems usually associated with the chroma-

tography of these compounds are evaluated, and methods used to circumvent these difficulties are discussed. This report arose as the result of an attempt to analyze, both qualitatively and quantitatively, several different types of reaction mixtures containing phosphorus compounds. Results indicate that commercially available equipment (gas chromatograph and packed columns) is sufficient, without modification, to give good resolution and rapid analysis of a large variety of organophosphorus substances."

This paper has substantially improved our knowledge of the analysis of microamounts of phosphorus compounds, and may serve to increase the accuracy and facility with which the analysis of toxic war gases can be made. We feel this is a good example of how basic research in mission-oriented areas of science can help to back up a strong technology for defense in this day of "Tomorrow's Weapons." ★

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solar radio noise: potential index to environmental prediction

JOHN P. CASTELLI, Space Physics Laboratory, AFCRL

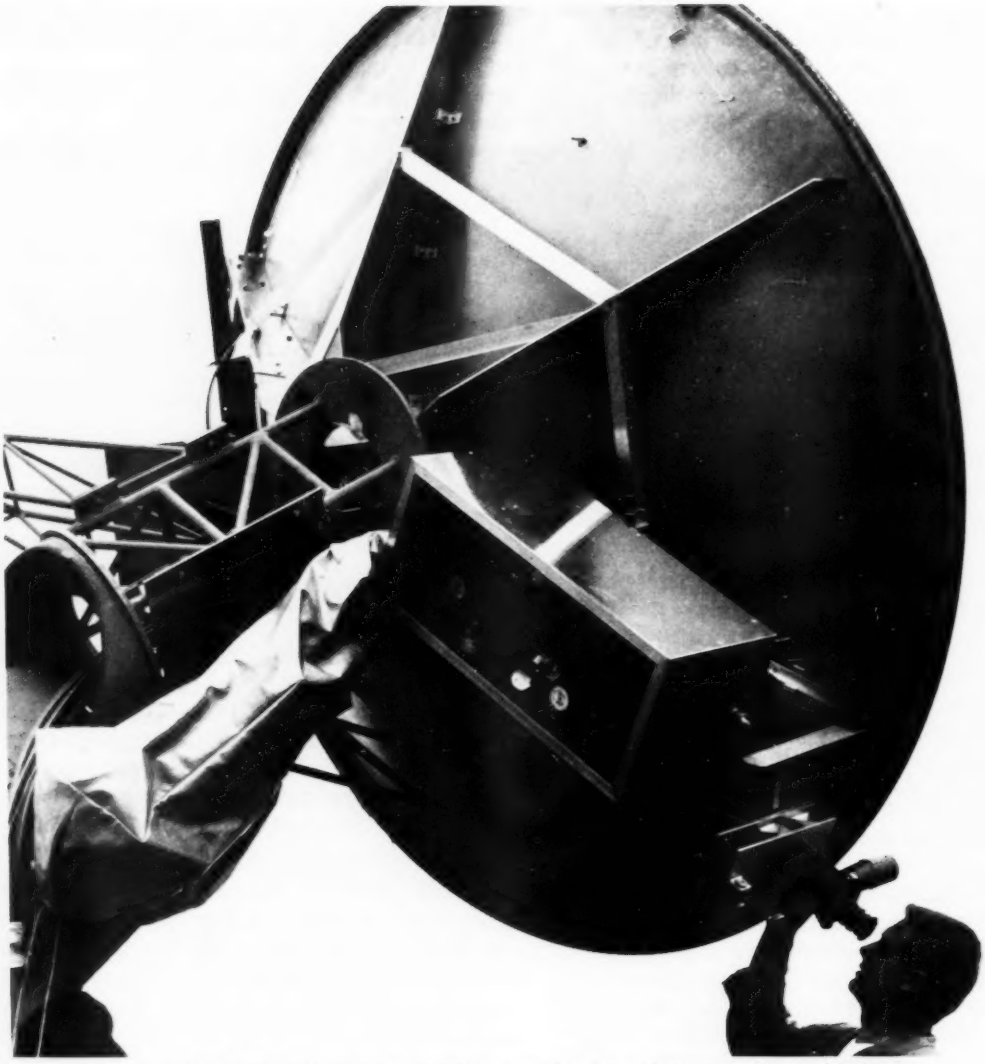
The sun radiates energy over a range of radio frequencies. At any given frequency, the strength or flux of these emissions changes rapidly and often unpredictably.

How do changes in flux at certain frequencies correlate with solar and terrestrial effects?--solar proton showers, solar flares, magnetic storms, auroral displays, and radio communications blackout? Can certain characteristic changes in radio emissions be identified as precursors to these observed effects? Can they provide a basis for prediction?

In a general, qualitative way we already know something of the positive relationships. But we don't have enough continuous, long-term data to state these relationships with any degree of assurance. In January 1966, AFCRL began a study that may lead to precise formulations. Under this program, five different frequencies are monitored continuously from sunup to sundown seven days a week. Absolute flux measurements of the sun at these five frequencies are monitored, and consistent records will be maintained over long periods. No other radio observatory in the U.S. is making such continuous, long-term measurements. Although some equipment modifications will probably be made to the program between now and September 1966, planning calls for completely uniform and continuous monitoring after that date.

Records are made available to both the Air Weather Service (AWS), which has the Air Force responsibility for predicting the occurrence of all environmental events affecting Air Force and DoD operations, and to the general scientific community. These records are distributed daily. Solar-noise bursts are reported immediately. AWS personnel at Sagamore Hill Observatory provide these data to AWS headquarters by TWX.

Two of the smaller radio telescopes at the AFCRL Sagamore Hill Radio Observatory are used in these studies--one with a 28-foot dish, the other with a dish of 8 feet. The 8-foot telescope provides flux values at 2700 mc and 8800 mc. A multifrequency feed (which includes provision for 5000 mc output) is used on the equatorially mounted antenna. The outputs of each of the radiometers are



An 8-foot telescope is used to record solar radiation at 606 and 8800 mc.

recorded on dual channel paper records. One channel of limited dynamic range is used for the small daily variations of the flux, the slowly varying components of the sun's radiation. The second channel is used for recording the burst activity which may rise to many times the solar background.

The equatorially mounted 28-foot antenna has 2 radiometers at its output, one at 606 mc and the second at 1415 mc. It is also set up to record the flux of the slowly varying component and the bursts from solar flares. The output of this unit is fed to digital equipment as well as to paper chart recorders. This unit is presently not in continuous operation, since final adjustments of the antenna and the recording equipment are taking place.

The flux of radio emissions peaks at different frequencies, depending on the source region. Sunspots emit energy in the spectral range of 1415 to 10,000 mc. At 606 mc, the radiation is from the outer layers of the solar atmosphere, the corona. At 8800 mc, the radiation is from the chromosphere, closer

The 28-foot radio telescope (foreground) will be used to record emissions from sunspots between 1415 and 10,000 mc. AFCRL's 150-foot radio telescope is shown in the background. These telescopes are located at the Sagamore Hill Radio Observatory at Hamilton, Mass., which is one of the most complete radio observatories in the country.

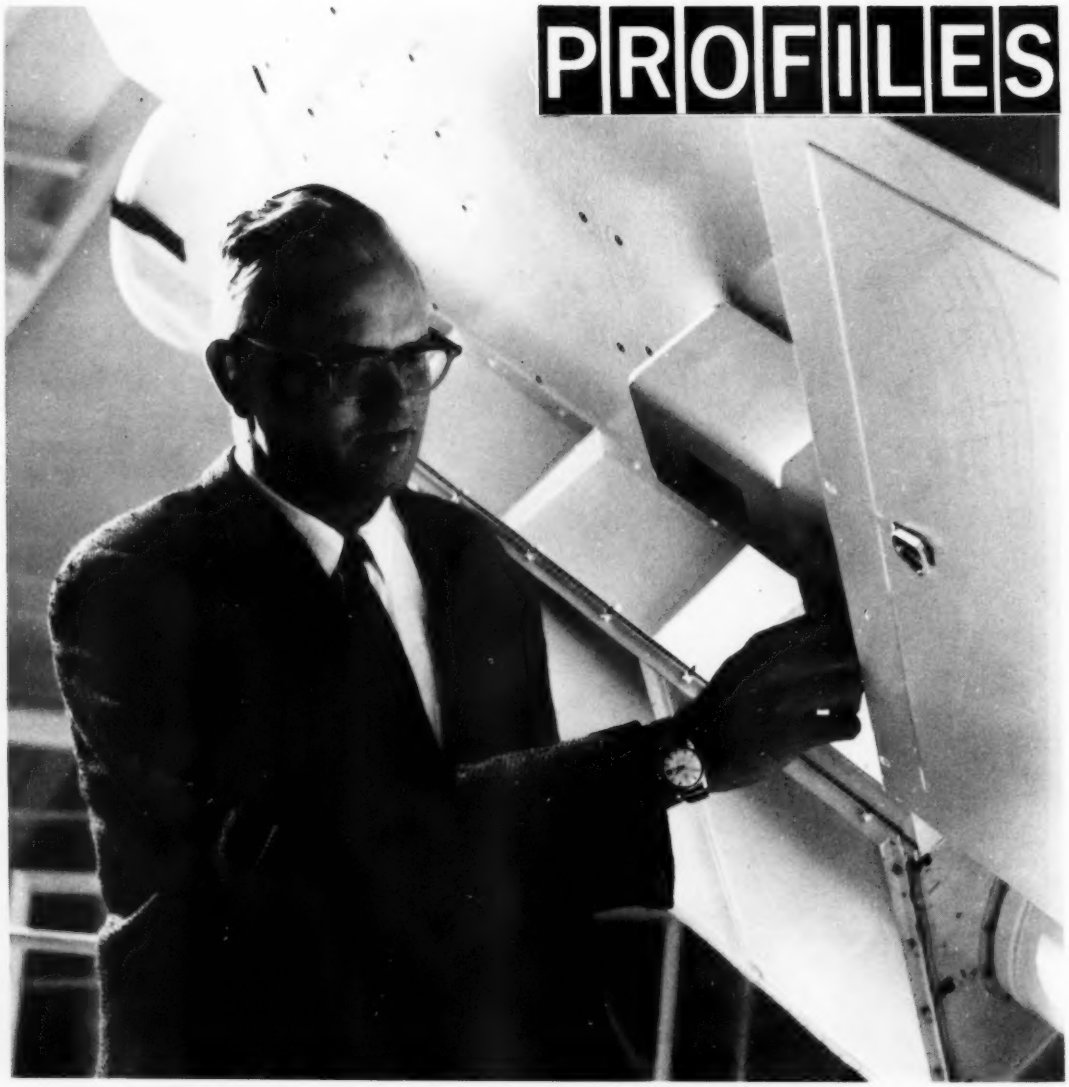
to the sun's visible surface.

Sunspot regions have, historically, been of primary interest. From these centers of activity, flares are generated. Those studying prediction techniques hope to be able to distinguish unambiguously between those centers of sunspot activity that produce geomagnetic events and those that have no terrestrial effects.

In addition to the two radio telescopes to be permanently assigned to the solar-noise monitoring program, other receivers will be used periodically for special observations. An 84-foot antenna, for example, will be used for more precise analysis of radiation from the corona and the chromosphere.

This research was funded under the Air Force Independent Research Fund. ★

PROFILES



Dr. Richard B. Dunn is a physicist at the Sacramento Peak Observatory, Sunspot, New Mexico, Air Force Cambridge Research Laboratories. From the University of Minnesota he received the degrees of Bachelor of Mechanical Engineering in 1949 and Master of Science in 1950. In the fall of 1950, he became a teaching fellow and graduate student in astronomy at Harvard University. Upon completion, in 1960, of his thesis entitled "Photometry of the Solar Chromosphere," Harvard University awarded him the degree of Ph.D. Dr. Dunn joined the staff of Sacramento Peak in 1953, and has been with AFCRL ever since. He is now engaged in work concerned with designing and constructing optical instruments for solar research. His observational work on the structure of the solar chromosphere and limb darkening profile in the continuum is outstanding for the meticulous care and ingenuity displayed in the elimination of instrumental and "seeing" effects. In addition to publishing a number of articles, Dr. Dunn has provided the design concepts for a unique solar vacuum telescope, which is described in this issue of the Review in the article, "Construction of Solar Vacuum Telescope to begin in 1966."

Dr. Denny D. Watson of the General Physics Research Laboratory, ARL, was author of "Some Nuclear-Structure Studies Using Gamma-Ray Angular Correlations" which appeared in the December 1965 issue of the OAR Research Review. (His "profile" is republished here because of an error in the December 1965 "OAR Profiles." The photo used in that issue was not of Dr. Watson, but of Dr. J. H. Winicour.) Dr. Watson is currently concerned with properties of excited states of Cl^{35}, new and improved methods for the analysis of gamma-ray angular correlation data, and the design of mechanical and electronic systems to provide for gamma-ray polarization measurements. He received his B.S. (Engineering Physics) in 1960, and his Ph.D. (Physics) in 1965, both from the University of Kansas. Prior to joining ARL, he was a research assistant, Nuclear Physics Laboratory, University of Kansas, from 1958 to 1964.

Mr. Michael Hawes, a member of the Thermomechanics Research Laboratory, ARL, is engaged in research in the direct conversion of fluid dynamic energy into electricity. The energy-conversion process necessitates consideration of the interplay of electrical, aerodynamic, and thermodynamic effects to achieve desirable operating characteristics of an electrofluid dynamic (EFD) generator. Typical output voltages are of the order of hundreds of kilovolts, with output currents in the milliampere range. Particular areas of research are the development of instrumentation and loading methods to match these output parameters, investigations into gas seeding methods, and dielectric testing with the aim of determining the most suitable gases to be used as the EFD transport medium. Mr. Hawes was graduated from the National University of Ireland (B.E. degree in Mechanical and Electrical Engineering, 1958). In this issue of the Review, he writes on "Electrofluid Dynamic Working Media for Direct Energy-Conversion Processes."

Dr. Yoon Soo Park has been a research physicist with the Solid State Physics Research Laboratory, ARL, from 1962 to the present. Prior to that, he was a research physicist with the D. H. Baldwin Company, a teaching assistant at the University of Alberta, and an instructor at Pusan University. He has a B.S. in Physics from the Seoul National University (1952), an M.S. in Physics from the University of Alberta (1955), and a Ph.D. in Physics from the University of Cincinnati (1963). He also has a number of publications to his credit. Currently, he is conducting research on the optical electrical properties of II-VI-compound semiconductors. In this issue of the Review, he writes on the "Band Structure of ZnO."

POLYMER DEFORMATION STUDIES

DR. ANTHONY J. MATUSZKO, Directorate of Chemical Sciences, AFOSR

With grant support from the Directorate of Chemical Sciences, AFOSR, Dr. Richard Stein and his co-workers at the University of Massachusetts have developed and applied a new method for the study of polymer deformation. The method involves the measurement of "dynamic birefringence" (double refraction) of a polymer film in which the stress, strain and birefringence are simultaneously observed. The mechanical and optical data obtained serve to characterize the deformation mechanism of the polymer, thereby yielding information about the molecular nature of structural changes which is not obtainable from mechanical spectra alone. A diagram of the type of apparatus used is shown in Figure 1.

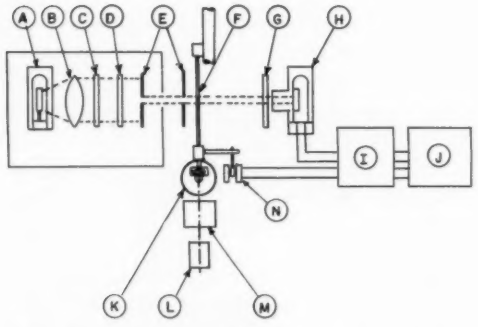


Fig. 1. The dynamic birefringence apparatus: (A) mercury light source; (B) condensing lens; (C) monochromatizing filter; (D) polarizer; (E) slits; (F) sample; (G) analyzer; (H) photomultiplier; (I) two- channel amplifier; (J) two-channel recorder; (K) eccentric drive; (L) motor; (M) variable-speed transmission; (N) linear variable differential transformer.

The birefringence of a polymer is a measure of its orientation. The finding that birefringence decreases with increasing frequency of strain is a consequence of the finite time required for the orientation of molecules, crystals, and crystalline superstructure in a polymer. If the sample is mechanically vibrated at a frequency corresponding to a period shorter than the orientation time of a particular structural mechanism, that mechanism will not contribute to the birefringence change at the particular frequency. As the frequency is lowered, more mechanisms contribute, and the birefringence increases in a manner dependent upon the time dependence of polymer mobility.

A thorough study was made of the dynamic mechanical and optical properties of a number of polymeric systems such as polyethylene, polypropylene, etc. Through the results obtained by the dynamic birefringence and related techniques, a new picture of the deformation of crystalline polymers has evolved, involving the rapid deformation of the crystalline superstructure as the sample is deformed, followed by a slower viscoelastic reorientation of the constituent crystals.

In order to learn more about crystal-orientation changes in the polymer when deformed, the University of Massachusetts research group developed a dynamic X-ray diffraction technique which is capable of directly measuring rates of such changes. This involves an "X-ray stroboscope" technique in which a sample is vibrated in the X-ray beam. The output of the detector of the diffracted radiation is distributed among four scalers by a commutator operating in synchronism with the sample vibration (Figure 2). Preliminary experiments have indicated a crystal-orientation response time comparable with that deduced from dynamic birefringence studies (1) (of the order of a second for polyethylene at room temperature).

In one other phase of this study, Dr. Stein and co-workers have developed a high-speed

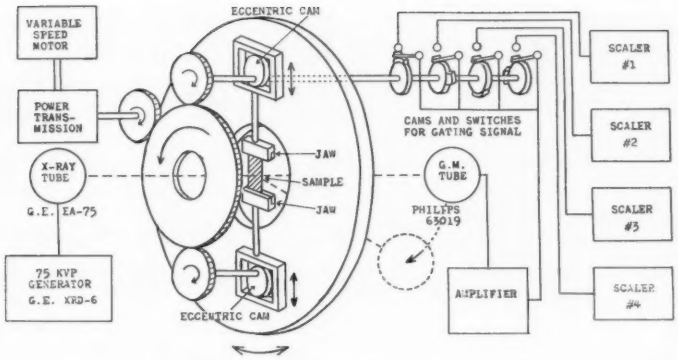


Fig. 2. A diagrammatic sketch of the dynamic diffractometer.

motion-picture technique to learn more about polymer deformations. When used in connection with a high-speed elongation apparatus and a continuous gas laser, this apparatus is capable of taking light-scattering movies of sample elongations. (2)

This research on polymers will be useful to the Air Force in better understanding and thereby eliminating factors which cause polymeric materials to degrade or crack under extreme stress. ★

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ANATOMY OF A SEVERE STORM

METEOROLOGY LABORATORY, AFCRL

So varied are the driving forces and physical manifestations of the severe local storm that it defies complete description, let alone complete understanding. From pieces of the puzzle gathered on a number of different occasions it is possible to synthesize a general picture of a severe local storm, but rarely has it been possible to approach adequate description of the many aspects of a single storm or group of storms from information gathered on a single occasion. This volume now attempts to do just that.

This foreword introduces a 346-page AFCRL special report, A Family Outbreak of Severe Local Storms--A Comprehensive Study of Storms in Oklahoma on 26 May 1963, (AFCRL-65-695-I). The report covers the results of the most complete series of observations ever made of a single storm. These results, in turn, provide a number of new insights into the behavior of the severe local storm.

To set the stage for his discussion of the 26 May 1963 family of storms, Dr. Keith A. Browning, editor of the 16-chapter report, devotes the first few chapters to an analysis of the over-all weather picture across the U.S. and in Oklahoma on the day of the storm. Observations were made south of Oklahoma City, in an area highly subject to severe local storms during the spring and early summer. Some eight AFCRL meteorologists participated in the study, together with meteorologists of Chicago University and the U.S. Weather Bureau, and researchers from Pennsylvania State University, Hazleton-Nuclear Science Corporation, Litton Systems, Inc., and Stanford University.

Meteorological equipments and sensors of great variety provided the data--a Tiros satellite, weather radar, aircraft, and devices to monitor bursts of radio static (sferics).

Standard monitoring equipments for measuring pressures, winds, humidities and temperatures were widely used throughout the area through which the storms passed. In addition, rainfall was collected for later analysis of its radioactivity, and giant hailstones were gathered and placed in deep freeze for laboratory examination. (Photographs of the cross sections of these hailstones in polarized and unpolarized light provide excellent information on their formation and growth.)

The family of storms on 26 May began to form along a cold front southwest of Oklahoma City about 1 p.m. and moved in an east-northeasterly direction. Eleven individual storm cells comprised this family, and the tops of their towering cumulonimbus clouds merged together to form a giant anvil canopy at altitudes between 30,000 and 50,000 feet. A number of these storms produced giant hail and tornadoes. Observers on the ground were able to watch the formation and behavior of two of these awesome funnel clouds. From the extensive observations, detailed models of precipitation trajectories and air-flow patterns were derived.

The conclusions contained in each chapter (prepared by various participants) are too numerous to summarize here; but one of the more significant generalizations in the report is contained in Browning's introduction: "As emphasized in the following chapters, severe local storms are quite different from nonsevere storms. They are not merely scaled-up thunderstorms, but have a character all their own." One of the primary ways in which this difference is manifested is in the life cycles of these two types of storms. An ordinary storm passes through three stages: the cumulus, or formative stage; the ordinary mature stage; and the dissipating stage. However, instead of dissipating after passing through the ordinary stage, the severe storm, which had been comprised of several subcells, evolves into a large and sometimes persistent single cell. It is during this stage that tornadic activity, also very characteristic of the severe local storm, develops. ★

IONOSPHERIC FLYING LABORATORY UNDERGOES MAJOR MODIFICATIONS

UPPER ATMOSPHERE
PHYSICS LABORATORY, AFCRL

AFCRL's highly instrumented KC-135 ionospheric flying laboratory has recently undergone major modifications to incorporate new equipments which will make the aircraft an incomparable ionospheric research facility. Most important of the modifications was the installation of a second hyperhemispherical dome (atop the fuselage) to accommodate a 35-mm all-sky camera and a granger ionospheric sounder. This is the first time such a sounder has been installed in an aircraft.

This unique aircraft with its great variety of instrumentation permits AFCRL scientists to conduct ionospheric studies all over the world. The aircraft is flown under the direction of Dr. George J. Gassmann as part of AFCRL's upper-atmosphere research program.

The KC-135 will be used for research in such areas as electrojet studies, aurora, air glow, arctic propagation studies, ionospheric perturbations and ionospheric densities.

Among the other equipments in the aircraft are a gamma-ray monitor for cosmic-radiation studies, photometers, visible and infrared spectrometers, day and night polarimeters, and various all-sky and narrow-field cameras to record natural and artificial air-glow phenomena.

A fluxgate magnetometer is used to measure total magnetic-field intensity. A periscope, interlocked to directional cameras and a photometer, provides servo control of these equipments. A precision timing unit provides the time base for all equipment. Data are recorded on magnetic tape, film and chart.

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Photo 1. The KC-135 Ionospheric Flying Laboratory

Photo 2. The three domes of the aircraft can be seen here. The first dome at the left contains a mirror system for spectrographs separating in the visible and infrared regions. In the center, the tip of the periscope is shown surrounded by an airfoil to give aerodynamical stability. The dome at the far right houses the photometer.

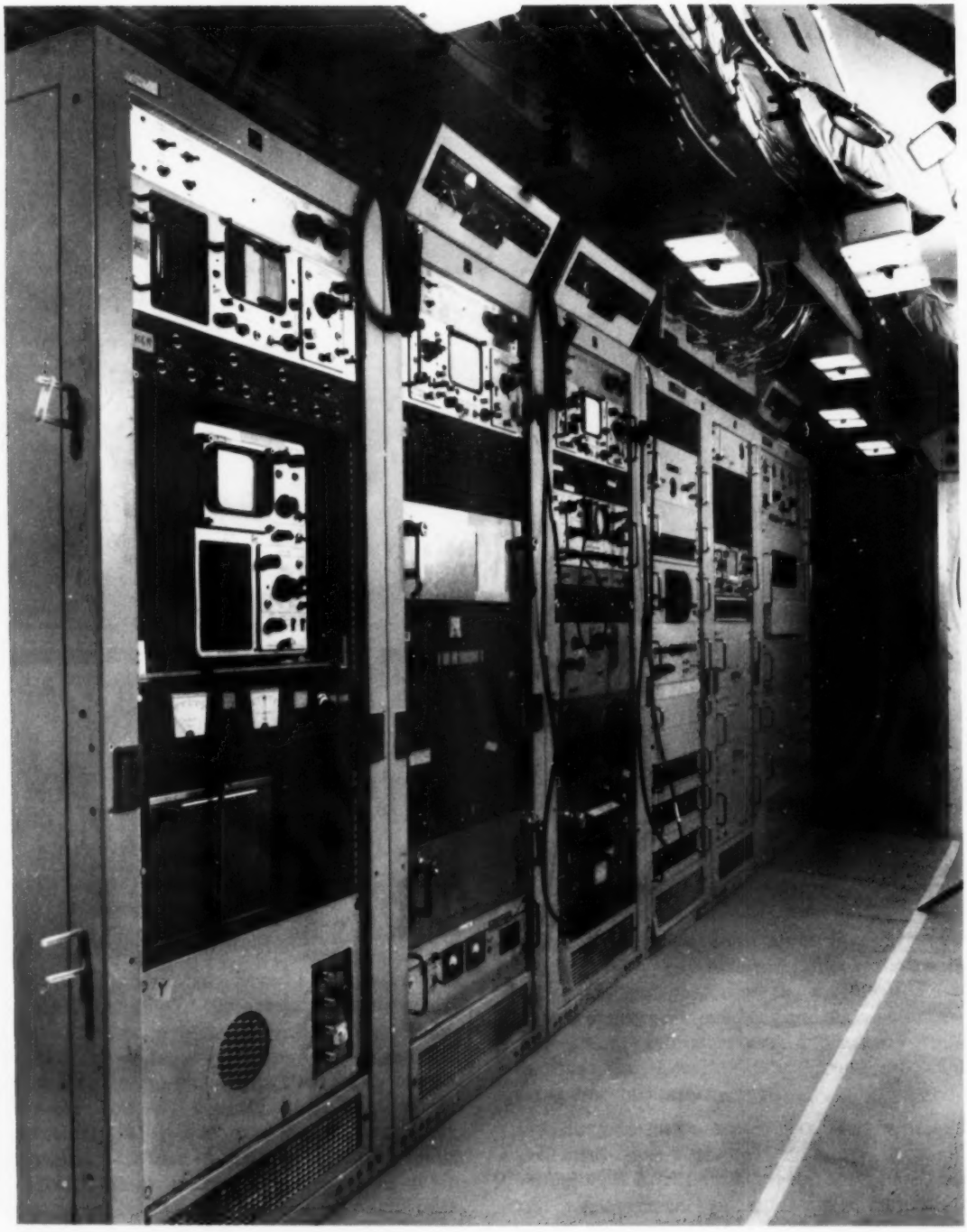
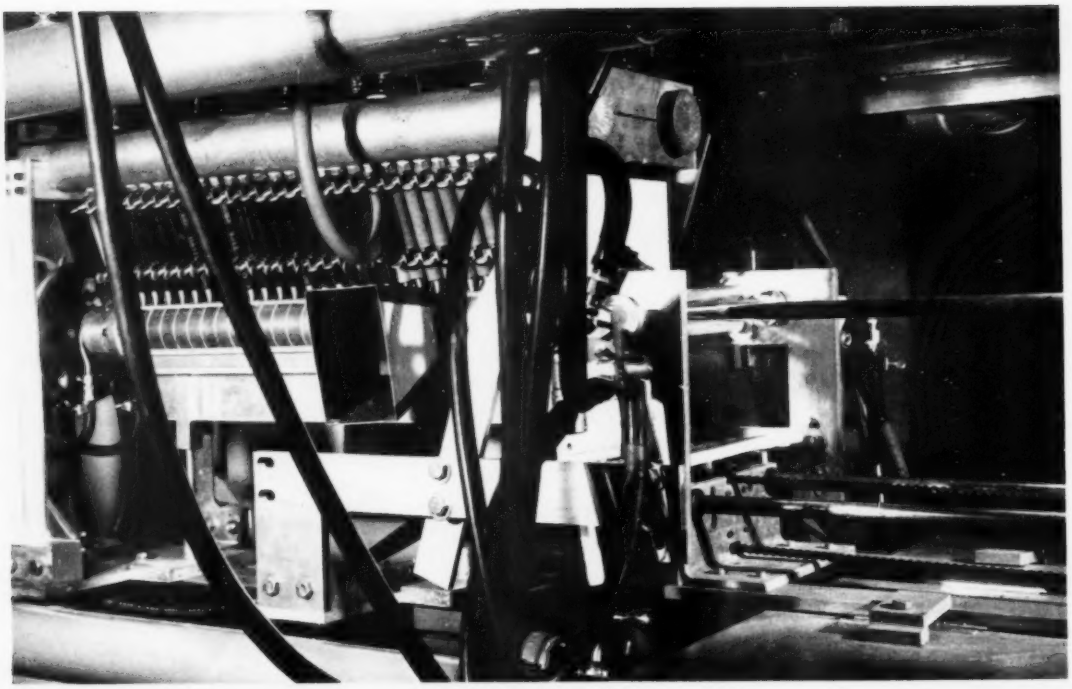


Photo 3. Here may be seen the heart of the instrumentation aboard the aircraft. The various racks consist primarily of power stages for transmitters and various recording devices.

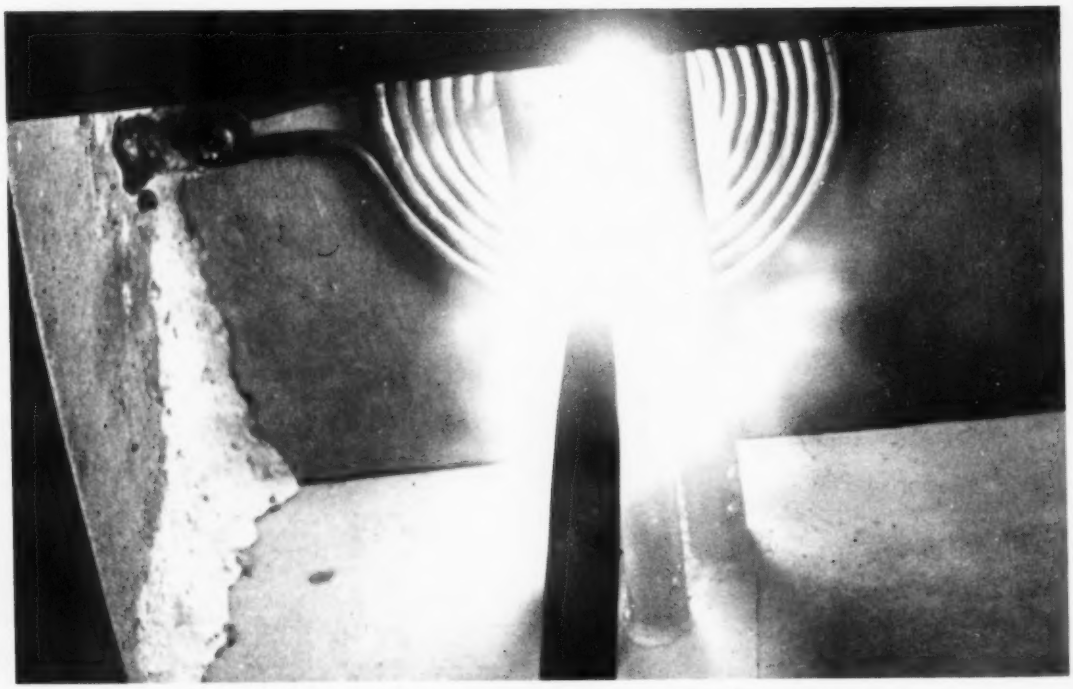
EFFECTS OF VORTEX FLOW

Most of today's high-enthalpy arc-heating devices utilize vortex flow around the arc column. However, the effects of the vortex flow on heat transfer from the arc to the gas are not at all understood, and strong controversies exist as to its value. Thus, ARL's Thermomechanics Research Laboratory, under an in-house study as the first phase of the program on gas-arc interaction, is investigating the effect of a vortex flow field on arc characteristics and on the heat transfer from a coaxial arc column. For this study, the simplest possible arc model was chosen: a very long arc column drawn coaxially within a cylindrical tube of 2" diameter through which nitrogen gas flows at controlled speed with a continuously variable rotational component. Through adjustments of the gas-injection angle, the vortex strength of the flow field may be changed without affecting the mass flow through the system. The arc, drawn up to 33 inches in length between movable cooled electrodes, is operated with alternating current at a power level up to 150 kw at about 1200 volts.

Control Console, Vortex-Stabilized Arc



Vortex-Stabilized Arc



Vortex-Stabilized Arc in Operation (Closeup Showing Arc Flame)